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Hydrological Conditions for Atlantic Salmon Rivers in the Maritime Provinces in 1998

by

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ABSTRACT

This paper provides 1998 and historical information on hydrological conditions for 7 selected Atlantic salmon (*Salmo salar*) rivers within the Maritime Region of DFO. High and low flows for each river were calculated based on historical annual high and low flow series. Stream water temperatures were reported in 17 river systems.

Discharges were above normal in winter 1998. Record high monthly flows were observed in March in Restigouche and Southwest Miramichi rivers. The spring breakup of 1998 was early with peak flows in March. The spring breakup was generally characterized as average with most rivers having floods between a 2-year and 5-year flood event in New Brunswick and Prince Edward Island. Most rivers in Nova Scotia showed similar results (2-year flood events) except for St. Marys River, which experienced a 20-year flood.

Low flow conditions in 1998 were present for a short period of time in August. Deficient flows and record low flows were monitored in NB and NS. On a daily basis, most rivers did not fall to the 2-year low flow this year. LaHave River experienced a 2-year low flow, and Northeast Margaree was the most affected in terms of low water conditions with a 50-year low flow event.

River water temperatures in 1998 were characterized by three events between late June to mid-August. In the Saint-John River system, Nashwaak River reached the highest peak temperature at 27.1 °C. Kennebecasis River was colder with peak temperature at 23.4 °C. The highest recorded water temperature in Morell River (PEI) occurred at McKenna culvert at 24.4 °C.

In the Miramichi River basin, most rivers reached their peak water temperature on August 10. Sites in the Northwest Miramichi system included: Catamaran Brook (19.7 °C), Little Southwest Miramichi River (26.7 °C), Cassilis (25.6 °C) and Tomogonops River (27.3 °C). In the Southwest Miramichi River, the site at Wade showed the highest recorded temperature at 27.1 °C. Water temperatures for other sites in the Southwest Miramichi River recorded peak values of: 25.6 °C (Sister's Brook), 25.7 °C (Millerton), and 26.8 °C (Nelson).

RÉSUMÉ

Le présent article a pour objet de fournir de l'information sur les conditions hydrologiques qui ont prévalu dans 7 rivières à saumon de l'Atlantique (*Salmo salar*) des provinces Maritimes en 1998. Les caractéristiques de débits de crue et d'étiage ont été calculées pour chaque rivière en utilisant des données historiques du débit maximum et minimum annuel. La température de l'eau a été présentée sur 17 rivières dans la région d'étude.

Le débit des rivières était supérieur à la normal pendant l'hiver 1998. Un débit fort extrême (record) a été observé en mars sur les rivières Restigouche et Southwest Miramichi. Les crues printanières étaient plus tôt en 1998 avec des débits de pointe en mars. Les débits de pointe étaient surtout caractérisés comme étant dans la moyenne avec une récurrence de 2 à 5 années au Nouveau-Brunswick et à l'Ile-du-Prince-Edouard. Les rivières en Nouvelle-Écosse démontrèrent des résultats similaires (crue de 2 années), sauf pour la rivière St. Marys dont la crue était de l'ordre de 20 années.

Les conditions de débits faibles en 1998 étaient sur une période courte en août. Des débits menusels plus faibles que la normale ainsi que des débits faibles extrêmes (record) ont été observés au Nouveau-Brunswick et en Nouvelle-Écosse. Sur une base journalière les débits faibles de plusieurs rivières étaient supérieurs aux débits d'une récurrence de 2 années sauf pour la rivière LaHave qui a atteint un débit faible d'une récurrence de 2 années. Les étiages les plus sévères ont été observés sur la rivière Margaree avec une récurrence d'environ 50 années.

Les variations de température de l'eau en 1998 ont été caractérisées par 3 événements de température élevées de la fin juin à la mi-août. Dans le bassin de la rivière Saint Jean, la rivière Nashwaak était la plus chaude avec une température maximale de 27.1 °C. La température de la rivière Kennebecasis était légèrement inférieure à 23.4 °C. La température maximale observée dans le bassin de la rivière Morell (I.-P.-E.) était de 24.4 °C au ponceau McKenna.

Dans le bassin de la rivière Miramichi, la plupart des rivières ont atteint leur température maximiale de 10 août. Les sites d'emplacement de la rivière Northwest Miramichi étaient : ruisseau Catamaran (19.7 °C), rivière Little Southwest Miramichi (26.7 °C), Cassilis (25.6 °C) et rivière Tomogonops (27.3 °C). Dans le bassin de la rivière Southwest Miramichi, le site avec la température maximale était à Wade avec une température de 27.1 °C. Les autres températures maximales étaient: 25.6 °C (ruisseau Sister), 25.7 °C (Millerton), et 26.8 °C (Nelson).

INTRODUCTION

Hydrological events can be important in the management of fisheries and aquatic resources. Some of these events such as streamflow variability can affect stream biota at different life stages and also during different seasons of the year. Salmonids can be affected by stream discharge such as high flows (Elwood and Waters 1969; Erman *et al.* 1988). Low flows and river water temperatures can play an important role in the distribution of fishes (Cunjak *et al.* 1993; Edwards *et al.* 1979). In order to increase our understanding of environmental conditions of particular Atlantic salmon rivers for the purpose of assessing Atlantic salmon stocks, we need to study the stream hydrology and associated extreme events for these rivers.

The objective of the present study is to analyze regional hydrological data for important Atlantic salmon rivers within the Maritimes Region for use in aquatic resource management. The specific objectives are: a) to provide an overview of the monthly precipitation and flow conditions for 7 rivers, b) to determine the high and low flow months in 1998, c) to determine the frequency of floods and low flow events in 1998, d) to identify abnormal streamflow events in the Maritimes Region, and e) to analyze data on high water temperature events for some Atlantic salmon rivers in the studied region.

METHODS

Historical and 1998 data on precipitation were obtained from Environment Canada for 7 sites in the Maritime Provinces and monthly precipitation data were presented.

Regional hydrological analysis was carried out using historical hydrometric data from gauged streams and rivers in the study region. Historical data and 1998 hydrometric data were also obtained from Environment Canada. These data were used to calculate high and low flow characteristics for different recurrence intervals (T-year events). Annual flood flows and low flows were fitted to a statistical distribution function in a frequency analysis to estimate the T-year events (Kite 1978). For instance, the 25-year (T = 25) low flow is a low flow which occurs on the average every 25 years such that 4 low

flow events occur in 100 years on average. Flood frequency analysis was based on a three-parameter lognormal distribution function and on historical annual flood observations (Kite 1978). In contrast, the type III extremal distribution was used to estimate the low flow frequency events using daily minimum discharge on an annual basis (Kite 1978).

Monthly flow characteristics for 1998 were compared to long-term monthly average flow conditions. The high and low flow months were estimated for each river system. In the present study, a flow above the 75th percentile identifies an excessive monthly flow condition while a flow below the 25th percentile denotes a deficient flow (Environment Canada 1995).

A study on the occurrences of high flow and low flow events was also carried out for three rivers in the Maritime Provinces. These rivers were selected to represent the overall hydrological conditions of the study area. High flow events were studied on an annual basis, during winter (Jan. to Mar.) and during the month of June. The winter peak flows can inform on potential winter breakup (e.g. ice jams) and other winter disturbances. High flows in June were also considered because this is a critical life stage for emerging salmon fry. The occurrence of low flow events was studied on an annual basis, during the winter (Jan. to Mar.) and summer period (Jul. to Oct.).

High water temperature events were studied for 17 sites throughout the Maritime Provinces. Mean daily water temperature values as well as peak temperatures were considered in the analysis. Also, the number of days on which each river exceeded 23 °C was analyzed.

Study rivers

The study region comprises 7 Atlantic salmon rivers within the Maritime Provinces for hydrological studies and 17 water temperature sites (Figure 1). These rivers are: Saint John River (01AK010, NB), Restigouche River (01BJ007, NB), Southwest Miramichi River (01BO001, NB), Wilmot River (01CD003, PEI), Northeast Margaree River (01FB001, NS), St. Marys River (01EO001, NS), and LaHave River (01EF001, NS).

The drainage basin of the studied rivers ranged from 45.4 km^2 (Wilmot River) to 39900 km^2 (Saint John River; Table 1). LaHave and St. Marys Rivers have the longest daily discharge time series with over 80 years of record. The mean annual flow (MAF), which is a function of drainage area, varies between 0.922 m^3/s for Wilmot River to 810 m^3/s for Saint John River. To compare discharge between basins of different sizes, the mean annual runoff was used. This represents the mean annual flow (MAF) expressed in unit discharge in mm (discharge per drainage area). The region has a wide range of runoff characteristics depending on parameters such as the amount of rainfall, soil type, etc. Northern New Brunswick (NB) and Prince Edward Island (PEI) showed the lowest runoff with only 640 mm (Saint John River, NB and Wilmot, PEI) and 665 mm (Restigouche River, NB) compared to more than double this value at 1485 in Cape Breton (Northeast Margaree River, Nova Scotia - NS). The precipitation varies from 1010 mm to 1600 mm (Table 1). The coefficient of variation (CV) of monthly flow characteristics showed more stable flow regime for some rivers than for other rivers. For instance, Wilmot River has a more stable flow regime with a CV of 0.49 compared to Restigouche River with a CV of 1.11 (Table 1).

RESULTS

PRECIPITATION IN 1998

Long-term precipitation data (1953-1990) are presented in Table 2 for comparative purposes. The highest monthly precipitation in 1998 was recorded in Kejimkujik in January with a total value of 216 mm. In contrast, the lowest precipitation recorded in the region was in Saint John with a precipitation in July of only 25.8 mm. Most area showed above average precipitation in January and March of 1998(Table 2). The Maritime provinces showed below average precipitation in June and November except for Halifax. Other months showed close to average precipitation in 1998.

HYDROLOGICAL CONDITIONS IN 1998

In general, winter flows (January to March of 1998) were excessive (Table 3). The greatest deviation from the long-term monthly flow was observed in New Brunswick with flows higher than +200% (Restigouche and Southwest Miramichi Rivers Figure

2a) with discharge higher than 350 m^3/s for both rivers compared to an average flow of 60 m^3/s for March. The Southwest Miramichi River and Restigouche River experienced record flows in March (Table 3). In PEI and NS, most rivers experienced excessive flows in the winter of 1998.

The spring high flow of 1998 was early with peak flows in March, resulting in average to deficient flows in May. In fact, all Maritime rivers were excessive in March with New Brunswick rivers being most affected (Figure 2a and Table 3).

The summer monthly flows in 1998 were characterized as normal to deficient with a few excessive flows. A record low flow was recorded in LaHave River in May (Table 3). New Brunswick and part of Nova Scotia experienced excessive flows in July. Maritime rivers showed below normal values for August, and rivers in NS were most affected (Figure 2). A record low monthly flow was observed in Northeast Margaree River. In autumn, normal to excessive flows were present and record high flows were monitored for both Restigouche and Wilmot rivers (Table 3).

In 1998, higher annual discharges compared to 1997 were recorded throughout the Maritime provinces (Figure 3). This was largely due to excessive winter flow in February to March and in autumn (Table 3). Although 1998 showed higher flows than 1997, discharge were similar to 1996. Other years of interest were 1979 and 1990 when high water years were observed throughout the Maritime provinces. It was also observed that in NS, the annual flow variability was smaller over the past few years while in NB it has remained relatively high (Figure 3).

Daily discharges were more variable in LaHave and St.Marys rivers in winter of 1998 than in NB (Figure 4 and 5). A mid-winter thaw occurred late January (Jan 26) and resulted in peak flows for most rivers in NS. LaHave showed much variability in winter 1998 with three significant peaks of over 200 m^3/s (Figure 5b). Flows were low throughout the summer in Prince Edward Island this year (Figure 5a). A small peak flow was observed in LaHave River on July 2 with a discharge of 32.6 m^3/s. St.Marys and Northeast Margaree rivers showed small peak

flows in June 1998. These peak flows were observed for St. Marys on June 18 at 188 m^3/s and for Northeast Margaree River on June 5 at 43.3 m^3/s.

The maximum daily discharges in NB rivers were reached in April this year although three distinct peaks were observed between March to late April (March 11-13, April 2-3 and April 19-21; Figure 4). Peak flow for Saint John River was observed on April 19 at 5640 m^3/s (Figure 4b, day 109), an event less than a 2-year flood (Table 4). Restigouche River reached a discharge of 1720 m^3/s on April 2 (day 92) which is higher than a 2-year flood event. The Southwest Miramichi River peaked late April at 1110 m^3/s, which represents a flow within a 5-year event.

In PEI, the maximum daily discharge was observed March 10 (day 69) in Wilmot River (Figure 5a). The peak discharge was measured at 16 m^3/s and represents a 5-year flood event (Table 4). In Nova Scotia, LaHave River showed a maximum daily flow on March 11 at 238 m^3/s (Figure 5b; day 70). This peak flow represents an event below a 5-year flood. Marked variability in flow conditions was observed in LaHave River during the winter of 1998. A peak flow of 665 m^3/s was measured in St. Marys River on February 26 (day 57), which represents an event close to a 20-year flood event. For Northeast Margaree River, the peak flow was also observed on March 11, with a discharge of 181 m^3/s (higher than the 2-year flood).

Low flow conditions in 1998 were not as severe as in 1997 (Caissie 1998). In New Brunswick, the low flow period in 1998 was predominantly in mid-August although base flow conditions were good throughout the summer this year (Figure 4). For Saint John River, as in previous years, the regulated flow at the dam makes it difficult to assess the natural low flow conditions. Nonetheless, the lowest daily discharge was observed on both February 7 (day 38) and August 4 (day 216) at 74.5 m^3/s, which is higher than a 2-year event (Table 5). As for Restigouche River, the low flow period in 1998 was observed on August 24 (day 236) with a discharge of 47.6 m^3/s. This flow represents a higher discharge than a 2-year low flow. In Southwest Miramichi River, the low flow was observed on January 23

at 21.4 m^3/s. August 10 (day 222) also experienced a low flow at 22.2 m^3/s, which was a 2-year low flow event.

Wilmot River showed low flow conditions extending throughout the summer period in 1998 (Figure 5a). The daily minimum discharge was recorded on January 15 at 0.308 m^3/s which represents a low flow higher than the 2-year event. The summer low flow occurred on September 18 (day 261) at 0.361 m^3/s, a slightly higher discharge than the winter low. LaHave River fell to its low flow on August 17 (day 229) with a discharge of 1.60 m^3/s (Figure 5b). This low flow is in the vicinity of a 3-year low flow event (Table 5). Low flow conditions persisted until the end of September for LaHave River (Figure 5b). The low flow period for St. Marys River was observed on August 11 with a discharge of 2.14 m^3/s. This flow was higher than the 2-year low flow event. In Nova Scotia, Northeast Margaree River showed the most severe low flow conditions in the studied area in 1998 with a minimum daily discharge of only 1.47 m^3/s August 11 (day 223), a 50-year low flow event (Table 5)

In general, peak flows in 1998 were close to a 2-year flood event in New Brunswick except Southwest Miramichi River, which approached a 5-year event. In PEI, discharges were higher than a 5-year event. Nova Scotia rivers experienced between a 2-year and 5-year flood event, except for St. Marys which reached a 20-year high flow event. For low water conditions this year, many rivers in the Maritime Provinces showed flows higher than the 2-year low flow. This means that the low water conditions were not severe. The most affected river by low water conditions was Northeast Margaree River at close to a 50-year low flow.

The occurrence of high and low flow events was studied for three rivers in the Maritime Provinces over 4 decades (1960 to 1997). Results on high and low flow events are presented in Table 6. Annual peak flows for Southwest Miramichi were highest in 1970s with 6 years having peak flow higher than 1000 m^3/s (flow higher than the 2-year flood). The 1970s also showed a high occurrence of winter and June peak flows. Low flow events in the Miramichi were more important in 1960s and 1990s with over 5 years with flow lower than 20 m^3/s (2-year low flow). Winter low flow can be important in the Miramichi with the occurrence of up to 60

days of low water conditions one or two low flow years per decade (Table 6). The occurrence of low flow events was more important during the summer period, especially in the 1960s and 1990s with incidents totaling of over 100 days.

Data for St. Marys River showed that the 1960s and 1970s experienced the most years of peak flow having 7 years with peak flow higher than 400 m^3/s (close to a 2-year flood). The recent decades only showed 2 to 3 years. Winter peak flows are much higher in relative terms than those of New Brunswick. Results showed that winter peak flows have been important during the past 3 decades (Table 6). June high flow events were most important in the 1970s with 5 years of peak flow in June exceeding 100 m^3/s. Low flows in St. Marys River are predominately in summer and have been consistent throughout the decades. However, the duration of low flow conditions has been most important in the 1970s with a total count of 116 days. LaHave River showed a consistent pattern in high flows with 4 to 5 years per decade. Winter and June high flows were more prevalent in the 1970s. Low flow periods have predominately been observed in the 1960s and 1990s with 7 and 6 years. The incidence of low flow was twice as many in the 1960s and 1970s than for other decades.

STREAM WATER TEMPERATURES

River water temperatures were available for different locations within the Maritimes Region in 1998. The high water temperature events this year can be characterized by three different periods. The first event occurred close to June 27 (day 178), the second occurred close to July 17 (day 198), and the last high water temperature period occurred on August 10 (day 222).

Stream water temperature variations for Nashwaak River, Tobique Trap and Tobique Barrier are shown in Figure 6a (see Figure 1 for site location). Nashwaak River temperatures showed two distinct peaks of similar magnitude on July 16 (day 197) and on August 9 (day 221). During the July event, Nashwaak River reached a daily mean temperature of 24.9 °C. During the August event the Nashwaak River reach 24.8 °C. The maximum recorded temperature in Nashwaak River on 1998 occurred on August 10 at 27.1 °C (Table 7). At the Tobique River Trap, the maximum daily mean river temperature occurred on June 27 (day 178) at

23.4 °C (Figure 6a). Other events in July and August were of similar temperatures at 23.3 °C (day 199) and 22.6 °C (day 224). The maximum recorded temperature was 24.4 °C (Table 7). Results for Tobique River Barrier showed a maximum daily temperature of 22.1 °C on August 10 (day 222) with at maximum recorded temperature of 25.6 °C on August 26 (day 238, Table 7).

It was observed that the Mactaquac Fishway temperatures were less variable, and mean daily water temperatures remained over 20°C for most of the summer period (Figure 6b). The maximum recorded temperature for Mactaquac Fishway in 1998 occurred on August 11 at 24.5 °C (Table 7). The Kennebecasis River and Hammond River trap were also presented in Figure 6b. Kennebecasis River reached its maximum mean daily water temperature on July 17 (day 198) at 21.0 °C, with its maximum recorded temperature at 23.4 °C on August 10 (Table 7). Maximum mean daily water temperature at the Hammond River trap was measured at 24.4 °C on August 09 (day 221), and the maximum recorded temperature occurred on the same day at 26.1 °C. Kennebecasis River and Tobique River at the Barrier showed significantly lower water temperatures than Nashwaak River, Mactaquac Fishway, Hammond River, and Tobique Rivers at the Trap. In fact, only two events with daily mean temperature above 20 °C were observed on the Kennebecasis River and Tobique River (Barrier; Figure 6).

River water temperatures were available in the Morell River (PEI) in 1998 (Figure 7) at three locations: 1) McKenna's Culvert (South Branch), 2) St. Patrick's Pond (West Branch), and 3) Grants (Main Branch).

The highest daily mean temperature measured in the Morell River in 1998 occurred at McKenna's culvert on July 17 (day 198) at 22.5 °C (Figure 7). Maximum water temperature in the Morell River was also recorded at McKenna's culvert on that same day at 24.4 °C. Grants and St. Patrick's Pond showed similar water temperature time series in 1998. Maximum daily mean temperature occurred on July 17 at 21.1 °C (day 198) at Grants and on August 11 at 20.6 °C (day 223) at St. Patrick's Pond. The maximum recorded temperature between these two locations was reached on August 10 at 23.7 °C at St. Patrick's Pond.

River water temperatures were available at different locations within the Miramichi River basin in 1998 (Figure 8; see Figure 1 for site locations). Water temperatures were collected for 8 sites: 1) Southwest Miramichi River at Sister's Brook, 2) Southwest Miramichi River at Millerton, 3) Southwest Miramichi River at Nelson, 4) Southwest Miramichi River at Wade, 5) Northwest Miramichi River at Cassilis, 6) Little Southwest Miramichi River at Catamaran Brook, 7) Catamaran Brook, and 8) Tomogonops River.

Results in the Miramichi River were similar to those from other locations in NB with three high temperature events in summer of 1998. The July 16-17 event and August 10-11 were the highest in the Miramichi. Results showed that the Southwest Miramichi River at Millerton experienced the highest daily mean water temperatures in the Miramichi with value exceeding 25 °C (Figure 8a). During both July 18 (day 199) and August 10 (day 222), the mean daily temperature reached over 25 °C. The Southwest Miramichi River at Nelson reached its maximum temperature on July 16 at 24.4 °C. For the Southwest Miramichi River at Sister's Brook and at Wade, the maximum daily mean temperatures were recorded on August 10 at 22.3 °C and 24.6 °C respectively. It was observed that the water temperatures at Sister's Brook were relatively high early in the season with mean values exceeding 20 °C on May 15 (day 135; Figure 8a).

The thermal regimes of the Little Southwest Miramichi and the Tomogonops rivers were similar (Figure 8b). The Tomogonops River showed similar variation in water temperatures but values were lower. Catamaran Brook reached its peak water temperature (daily mean) on July 18 (day 199) at 18.0 °C. Other river systems reached their peak mean daily temperatures on the same day, August 10 (day 222, Figure 8b) at 23.0 °C (Tomogonops R.), 23.6°C (Little SW Miramichi R.), and 24.7°C (NW Miramichi R. at Cassilis).

Maximum recorded temperatures are also important for most rivers, and are presented in Table 7. Maximum recorded temperature in the Miramichi River system ranged between 19.7 °C at Catamaran Brook to 27.3 °C on the Tomogonops River. The maximum water temperature was reached on August 10 (day 222) for most rivers in the Miramichi. All monitored rivers in the Miramichi in 1998

exceeded water temperatures of 25 °C, except Catamaran Brook, which is the smallest studied tributary.

High temperature events can potentially effect aquatic biota depending on the recorded maximum temperature and the extent of such events. The last column in Table 7 presents the number of days with daily maximum temperature exceeding 23 °C. For instance, river water temperatures never reached 23 °C during the summer of 1998 for Catamaran Brook (NB) and Grants in the Morell River (PEI). Other rivers such as Kennebecasis River, Tobique River, Southwest Miramichi River at Sister's Brook, and Morell River (PEI) showed fewer than 10 days with temperatures over 23 °C in 1998 (Table 7). Northwest Miramichi River at Cassilis, Southwest Miramichi River at Nelson, Tomogonops River, Little Southwest Miramichi River and Mactaquac Fishway, all showed between 10 to 20 days with maximum temperatures above 23 °C. The most affected rivers in 1998 with high water temperatures include the Nashwaak and Hammond rivers, which showed over 30 days of peak temperatures exceeding 23 °C. These numbers were slightly higher than last year (Caissie 1998).

To compare water temperature in 1998 to previous years, the long-term data series from Catamaran Brook were used. Monthly water temperatures have been collected at Catamaran Brook since 1991 (Table 8). Highest monthly water temperature was recorded in July 1994 at 16.6 °C (Caissie 1995). In 1998, the highest monthly temperature was recorded in July at 14.7 °C. Monthly temperatures were higher than normal except for June. The most marked difference in 1998 occurred in the spring with higher temperatures. In fact, April showed a water temperature of 2.6 °C compared to the average of 0.6 °C.

SUMMARY

In summary, the streamflow conditions during 1998 were characterized by an above normal discharge in winter, especially during March in NB. The most affected rivers were Restigouche and Southwest Miramichi rivers with recorded monthly flows in March 1998.

The spring runoff in 1998 was characterized as normal in NB with peak flows close to a 2-year flood with the exception of Southwest Miramichi River at a 5-year flood event. PEI rivers also showed close to a 5-year flood event. In Nova Scotia, most rivers showed close to a 2-year flood, except St. Marys River, which showed close to a 20-year flood event. An important characteristic of spring peak flows in 1998 was that they occurred early. This year peak flows were observed late February to early March, and resulted in deficient flows in May, usually a high flow month.

Low flows were present only in August 1998, and for most rivers good flow to excessive flow conditions were present in autumn. New record low monthly flow was monitored in August for Northeast Margaree River.

High temperature events in summer of 1998 were very similar to previous years (e.g. 1996, 1997) and were not as severe as in 1994 and 1995. Highest water temperature in Nashwaak River in 1998 was 27.1 °C compared to 26.6 °C (1997; Caissie 1998) and 24.2 °C (1996; Caissie 1997). The maximum recorded temperature at Mactaquac Fishway was 24.5 °C compared to 22.9 °C (1997) and 22.6 °C (1996). Kennebecasis River showed 23.4°C this year compared to 20.6 °C (1997) and 21.1 °C (1996).

In the Miramichi River basin, the maximum water temperatures were slightly higher 1998 compared to 1997 and 1996. Little Southwest Miramichi River showed 26.7 °C compared to 24.9 °C (1997) and 26.1 °C (1996). Southwest Miramichi River at Sister's Brook showed 25.6 °C this year compared to 24.2 °C in 1997. Catamaran Brook monitored 19.7 °C in 1998 compared to 17.6 °C in 1997.

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Table 1. Hydrological characteristics of analyzed Atlantic salmon rivers in the Maritime Provinces.

River	Area[1] (km^2)	N (years)	MAF (m^3/s)	Runoff (mm)	CV	Prec. (mm)
Saint John River (NB)	39900	33	810	640	0.88	1010
Restigouche River (NB)	7740	30	163	665	1.11	1080
Southwest Miramichi R. (NB)	5050	50	116	725	0.82	1090
Wilmot River (PEI)	45.4	27	0.922	640	0.49	1100
LaHave River (NS)	1250	82	34.4	870	0.59	1420
St. Marys River (NS)	1350	82	43.0	1007	0.54	1350
Northeast Margaree R. (NS)	368	81	17.4	1485	0.61	1600

[1] Area = Drainage area in km^2; N = Number of years of data; MAF = Mean Annual Flow in m^3/s; Runoff = Unit discharge (discharge per unit of area) in mm; CV = coefficient of variation of monthly flows; Prec. = precipitation in mm.

Table 2. Long-term (*LT, 1953-1990*) monthly precipitation (mm) and conditions in 1998 for different areas in the Maritime Provinces. (First row of data represents the long-term precipitation while the second row represents the condition in 1998.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Chatham A (NB)	*LT*	85.2	69.5	86.6	86.3	88.1	84.5	97.8	95.9	87.8	95.2	104.4	105.5	1087
	1998	107.2	91.8	141.4	92.8	135.0	76.4	100.6	138.2	64.3[a]	131.5[a]	86.2[a]	71.2[a]	1237
Fredericton A (NB)	*LT*	93.3	84.3	90.4	83.4	94.0	86.9	84.5	99.4	92.3	93.1	110.7	118.8	1131
	1998	148.8	90.7	114.6	87.8	74.5	64.9	74.2	59.2	103.2	113.2	55.0	50.8	1037
Saint John A (NB)	*LT*	128.3	102.6	109.9	109.7	123.1	104.8	103.7	103.0	111.3	122.5	146.2	167.6	1433
	1998	177.8	64.8	117.5	112.9	51.0	55.7	25.8	92.9	117.4	161.4	94.9	65.2	1137
Charlottetown A (PEI)	*LT*	106.3	91.5	92.2	91.8	96.8	91.1	81.6	88.6	94.1	111.7	121.9	133.2	1201
	1998	135.4	50.2	91.2	111.4	68.5	197.1	43.3	52.9	109.5	117.4	96.8	37.8	1287
Kejimkujik (NS)	*LT*	141.3	113.0	117.6	108.8	101.5	96.7	104.2	87.9	97.1	116.4	145.0	167.5	1397
	1998	215.5	89.0	171.5	63.9	59.8	90.0	57.9	85.4	-	-	-	-	-
Maragaree Forks (NS)	*LT*	-	-	-	-	-	-	-	-	-	-	-	-	-
	1998	144.0	64.8	83.0	132.4	87.8	98.0	91.6	79.2	-	-	-	-	-
Halifax Int. A (NS)	*LT*	146.9	119.1	122.6	124.4	110.5	98.4	96.8	109.6	94.9	128.9	154.4	167.0	1474
	1998	204.5	129.9	117.4	85.5	72.5	142.4	77.5	66.6	124.3	161.0	132.8	-	

[a]. Data from Catamaran Brook.

Table 3. Long-term monthly and 1998 average flow conditions for different Atlantic salmon rivers in the Maritime Provinces (Environment Canada 1990). (First row of data for each river represents the long-term flow condition while the second row represents the 1998 discharges expressed in m^3/s; number of years of record for long-term data is shown in Table 1).

River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Saint John River (NB)	LT	376	376	508	2360	2320	763	431	408	386	604	657	566
	1998	168DR	270	1300E	3460E	1080D	360D	554E	194D	285	339	446	439
Restigouche River (NB)	LT	50.9	44.4	52.5	347	667	184	104	80.9	72.2	119	124	93.6
	1998	96.7E	104E	673ER	559E	347D	121	214E	91.4	135E	146	131	524ER
SW Miramichi R. (NB)	LT	56.7	49.8	66.4	316	318	112	60.0	54.7	54.1	89.5	116	98.8
	1998	30.6D	64.3E	352ER	548E	218	95.0	63.8	49.7	53.3	101	88.6	73.0
Wilmot River (PEI)	LT	1.07	0.932	1.62	1.94	1.21	0.773	0.572	0.494	0.434	0.499	0.636	0.884
	1998	0.771	1.18E	2.66E	2.00	1.02	0.709	0.533	0.429	0.433	0.613E	1.53ER	0.880
LaHave River (NS)	LT	47.0	38.4	53.3	73.3	38.9	20.6	11.3	8.97	8.89	19.8	42.7	50.7
	1998	69.8E	60.3E	93.4E	43.7D	13.2DR	5.33D	9.81	1.59D	3.42	34.4E	57.3E	-
St. Marys River (NS)	LT	51.1	40.3	55.3	91.2	57.1	23.8	14.4	15.1	16.0	34.2	58.0	59.0
	1998	81.2E	93.0E	98.0E	67.0	49.3	46.7E	23.0E	5.12	22.8	39.5	-	-
NE Margaree River (NS)	LT	15.3	11.0	12.3	27.1	43.4	15.5	6.80	7.56	9.38	16.2	22.8	19.1
	1998	9.28	12.1	33.1E	44.1E	30.8	9.79	3.99D	2.66DR	18.1E	10.1D	-	-

D= Deficient flow; E = Excessive flow; R = New record flow (see text for more details).

Table 4. Flood flow values determined from flood frequency analysis (using a 3-parameter lognormal distribution function) for seven Atlantic salmon rivers in the Maritime Provinces and for different recurrence intervals (T) in years. All flood flows are expressed in m^3/s.

	Recurrence interval (T) in years					
River	2	5	10	20	50	100
Saint John Rvier (NB)	5910	7738	8854	9867	11124	12032
Restigouche River (NB)	1491	2118	2488	2819	3220	3505
SW Miramichi R. (NB)	834	1164	1391	1613	1909	2137
Wilmot River (PEI)	11.6	15.3	17.4	19.2	21.2	22.6
LaHave River (NS)	195	284	363	454	596	721
St. Marys River (NS)	382	509	593	675	782	863
Northeast Margaree R. (NS)	166	225	266	306	359	400

Table 5. Low flow values determined from low flow frequency analysis (using a Extremal type III distribution function) for seven Atlantic salmon rivers in the Maritime Provinces and for different recurrence intervals (T) in years. All discharge values of low flows are expressed in m^3/s.

	Recurrence interval (T) in years					
River	2	5	10	20	50	100
Saint John River (NB)	70.0	54.9	48.4	43.6	38.7	35.8
Restigouche River (NB)	22.6	16.8	14.1	12.3	10.6	9.65
Southwest Miramichi R. (NB)	19.8	15.1	12.9	11.2	9.70	8.84
Wilmot River (PEI)	0.295	0.223	0.189	0.164	0.139	0.125
LaHave River (NS)	1.59	0.619	0.355	0.226	0.147	0.119
St. Marys River (NS)	1.64	0.682	0.407	0.267	0.177	0.144
Northeast Margaree R. (NS)	3.02	2.35	2.01	1.73	1.44	1.26

Table 6. Results on the number years with high flow and low flow events by decades. Values in parentheses represent the number of days within the decade with flows below the target value.

Southwest Miramichi River

Period	Annual Q>1000 m^3/s	Winter Q>250 m^3/s	June Q>250 m^3/s	Annual Q<20 m^3/s	Winter Q<20 m^3/s	Summer Q<20 m^3/s
1960-69	2	0	2	6	2 (44)	5 (126)
1970-79	6	5	3	3	0 (0)	2 (27)
1980-89	3	2	2	3	2 (60)	2 (34)
1990-97	2	1	1	5	1 (13)	4 (119)

St. Marys River

Period	Annual Q>400 m^3/s	Winter Q>300 m^3/s	June Q>100 m^3/s	Annual Q<1.6 m^3/s	Winter Q<1.6 m^3/s	Summer Q<1.6 m^3/s
1960-69	7	0	1	5	0	5 (111)
1970-79	7	4	5	4	0	4 (116)
1980-89	2	4	1	2	0	2 (56)
1990-97	3	5	2	5	0	5 (70)

LaHave River

Period	Annual Q>200 m^3/s	Winter Q>150 m^3/s	June Q>60 m^3/s	Annual Q<1.6 m^3/s	Winter Q<1.6 m^3/s	Summer Q<1.6 m^3/s
1960-69	5	1	0	7	0	7 (390)
1970-79	5	5	3	4	0	4 (111)
1980-89	4	3	1	5	0	5 (129)
1990-97	4	3	2	6	0	6 (270)

Winter = Jan. to Mar.; Summer = Jul. to Oct.

Table 7. Stream water temperature characteristics in selected Atlantic salmon rivers in the Maritime Provinces. Temperatures in deg. C.

River	Maximum daily mean	Maximum recorded	No of days above 23 °C
Nashwaak River (NB)	24.9 (Jul 16)	27.1 (Aug 09)	30
Mataquac Fishway (NB)	23.7 (Aug 11)	24.5 (Aug 11)	16
Kennebecasis River (NB)	21.0 (Jul 17)	23.4 (Aug 10)	2
Tobique R. at Trap (NB)	23.4 (Jun 27)	24.4 (Jul 18)	8
Tobique R. at Barrier (NB)	22.1 (Aug 10)	25.6 (Aug 26)	6
Hammond R. Trap (NB)	24.4 (Aug 09)	26.1 (Aug 09)	32
Catamaran Brook (NB)	18.0 (Jul 18)	19.7 (Aug 10)	0
LSW Miramichi R. (NB)	23.6 (Aug 10)	26.7 (Aug 10)	16
SW Mira. R. at Sister's Bk (NB)	22.3 (Aug 10)	25.6 (Aug 10)	8
SW Mira. R. at Millerton (NB)	25.3 (Aug 10)	25.7 (Aug 10)	22
SW Miramichi R. at Wade (NB)	24.6 (Aug 10)	27.1 (Aug 10)	22
NW Mira. R. at Cassilis (NB)	24.7 (Aug 10)	25.6 (Aug 10)	16
SW Miramichi R. at Nelson (NB)	24.4 (Jul 16)	26.8 (Jul 16)	12
Tomogonops River (NB)	23.0 (Aug 10)	27.3 (Aug 10)	15
Morell R. at Grants (PEI)	21.1 (Jul 17)	22.9 (Jul 16)	0
Morell R. at McKenna (PEI)	22.5 (Jul 17)	24.4 (Jul 17)	9
Morell R. at St. Patrick (PEI)	20.6 (Aug 11)	23.7 (Aug 10)	4

Table 8. Monthly water temperatures at Catamaran Brook Middle Reach (located in central New Brunswick, a part of the Miramichi River Basin). All temperatures are expressed in °C.

Month	Apr	May	Jun	Jul	Aug	Sep	Oct
1991	n/a	7.76	12.45 *	14.66	15.07 *	n/a	n/a
1992	n/a	8.11 *	11.55	12.15	12.86	11.56	5.58
1993	0.35	5.80	10.52	13.39	14.79	10.69	4.49
1994	0.75	4.98	12.41	16.58	15.22	10.26	5.55
1995	0.99	5.89	13.52	16.24	15.26	9.88	7.18
1996	0.72	5.41	13.63	14.29	15.22	11.51	6.01
1997	0.38	3.84	11.48	13.91	13.72	11.04	4.79
1998	2.55	8.91	11.40	14.70	14.27	11.31	6.51
Mthly Mean	0.64	5.61	12.19	14.46	14.51	10.82	5.60

Note : * indicates that these months had missing values, and therefore the average was calculated with a reduced sample and these months were not used in the calculation of the monthly mean. June 1991 (28 days), August 1991 (27 days), and May 1992 (19 days).

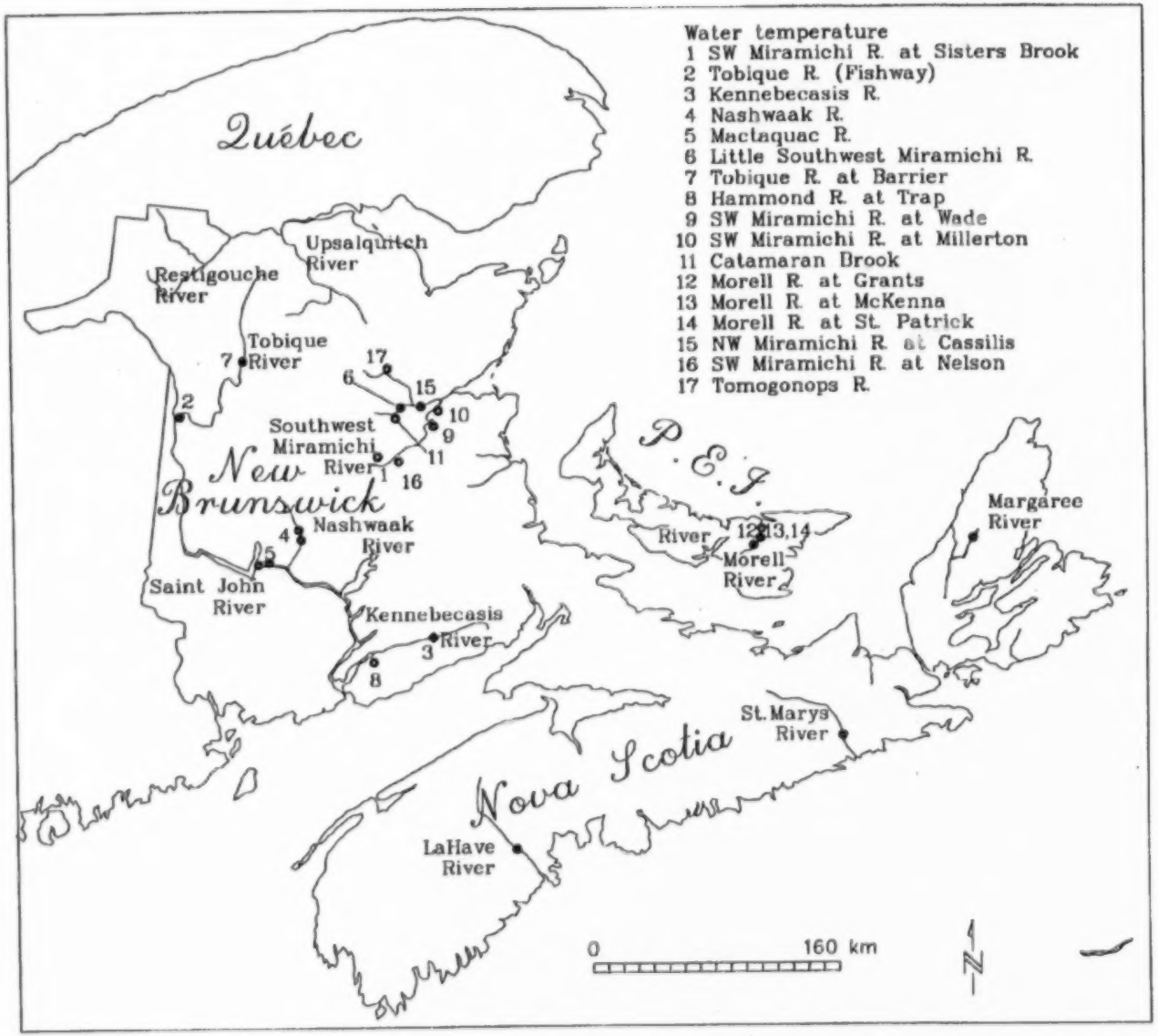

Figure 1. Location of hydrometric and water temperature stations on studied Atlantic salmon rivers in the Maritimes region.

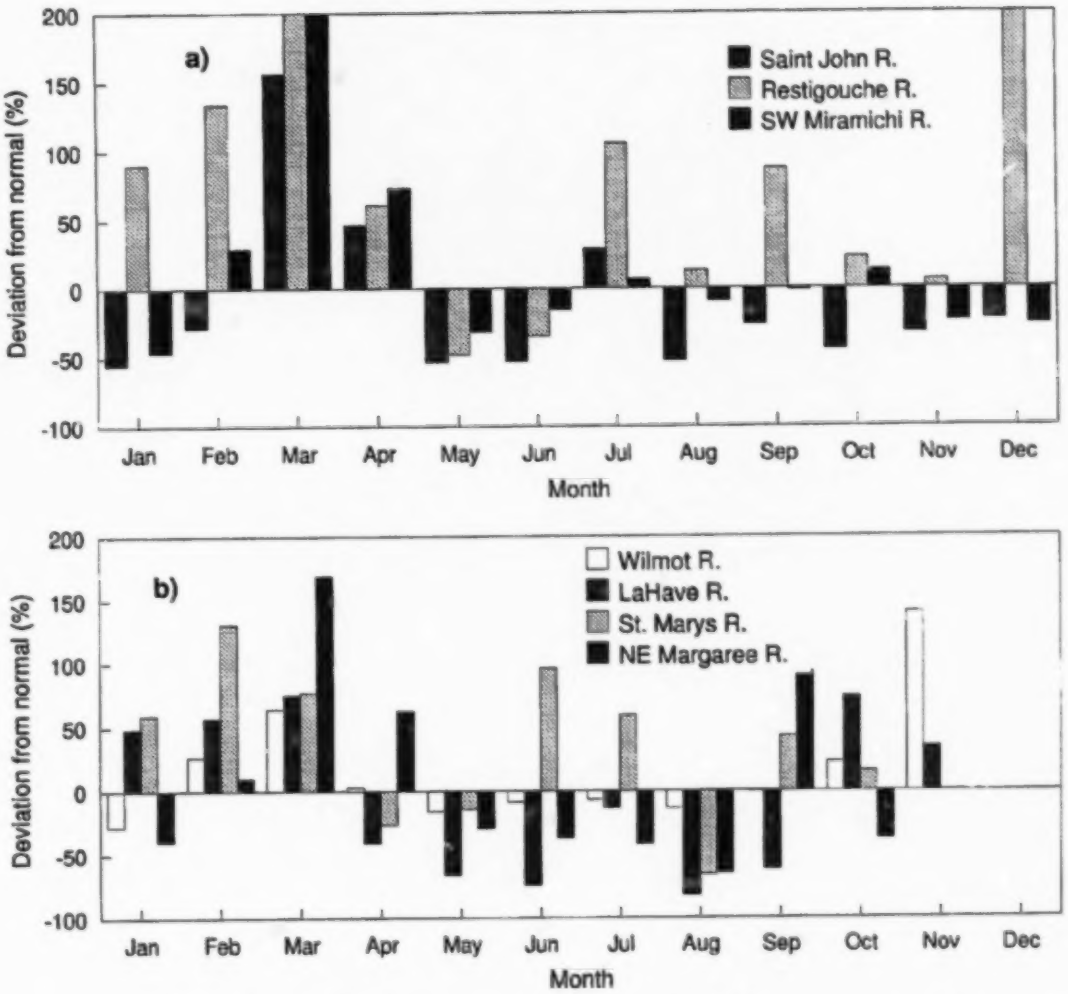

Figure 2. Deviation from mean monthly discharge in 1998 (in percentage, %) for studied rivers in the Maritime provinces.

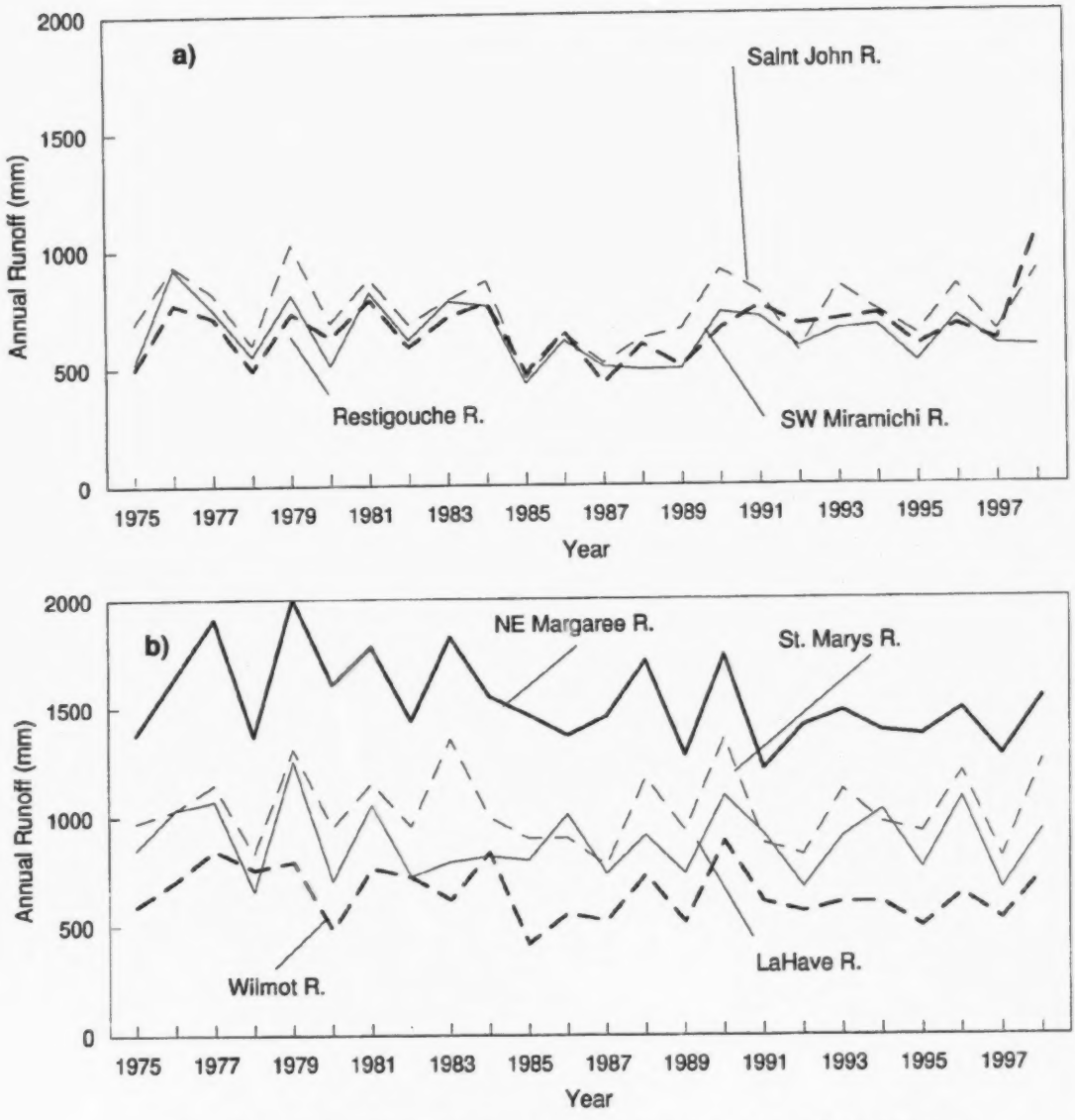

Figure 3. Mean annual runoff (mm) for Atlantic salmon rivers in the Martime provinces between 1975 and 1998.

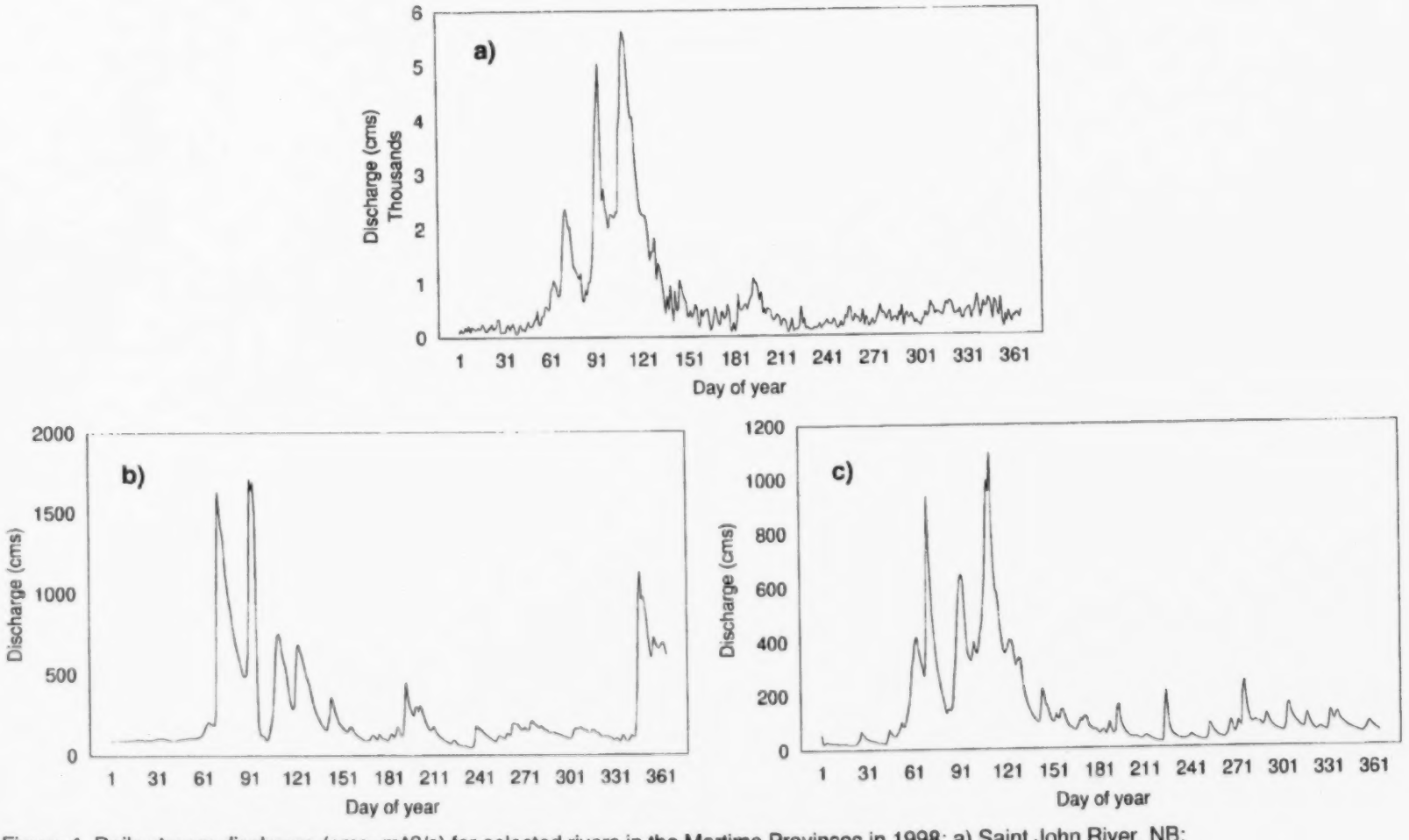

Figure 4. Daily stream discharge (cms=m^3/s) for selected rivers in the Martime Provinces in 1998: a) Saint John River, NB; b) Restigouche River, NB; and c) Southwest Miramichi River, NB.

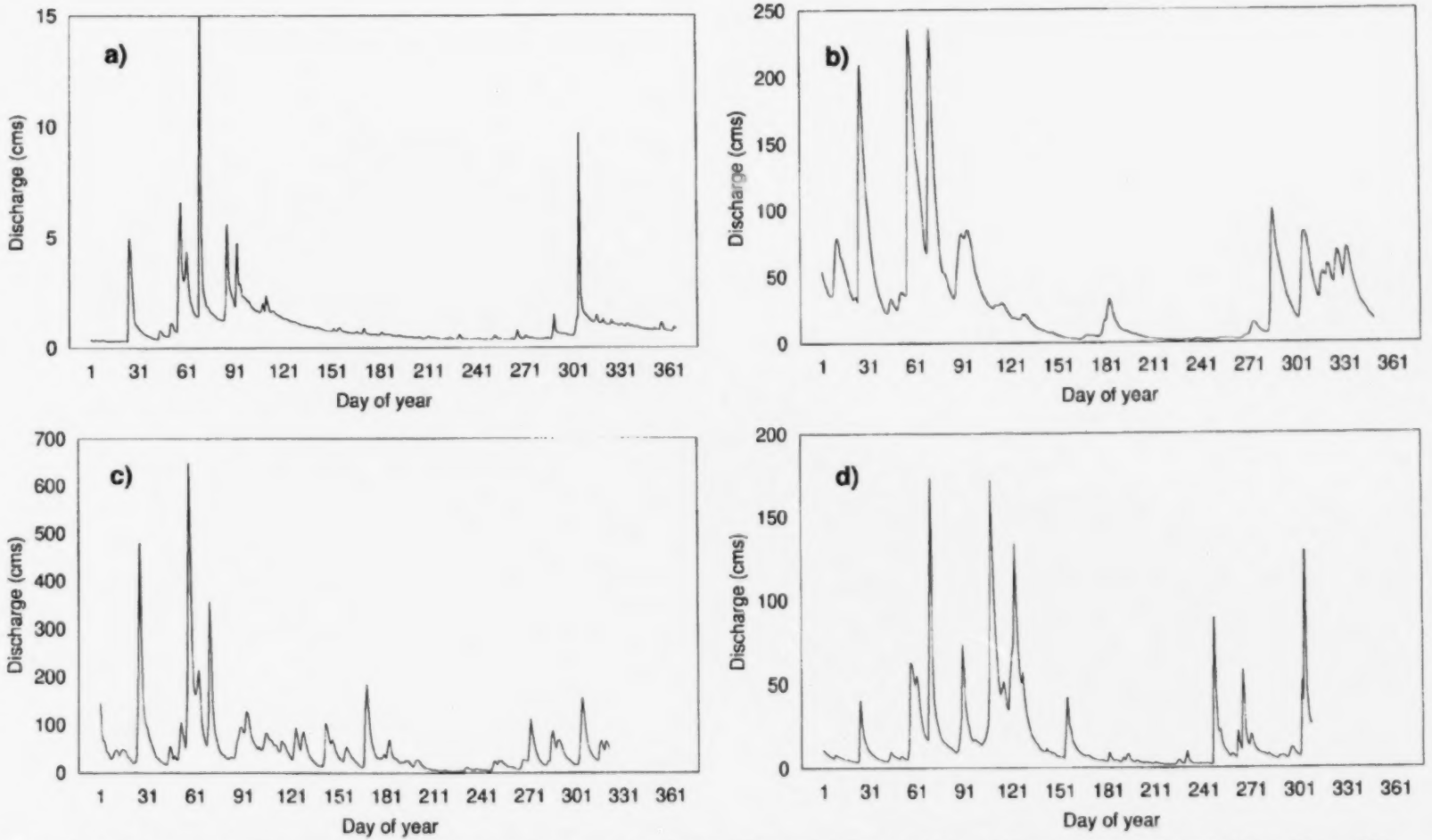

Figure 5. Daily stream discharge (cms=m^3/s) for selected rivers in the Maritime Provinces in 1998: a) Wilmot River, PEI; b) LaHave River, NS; c) St. Marys River, NS; and d) Northeast Margaree River, NS.

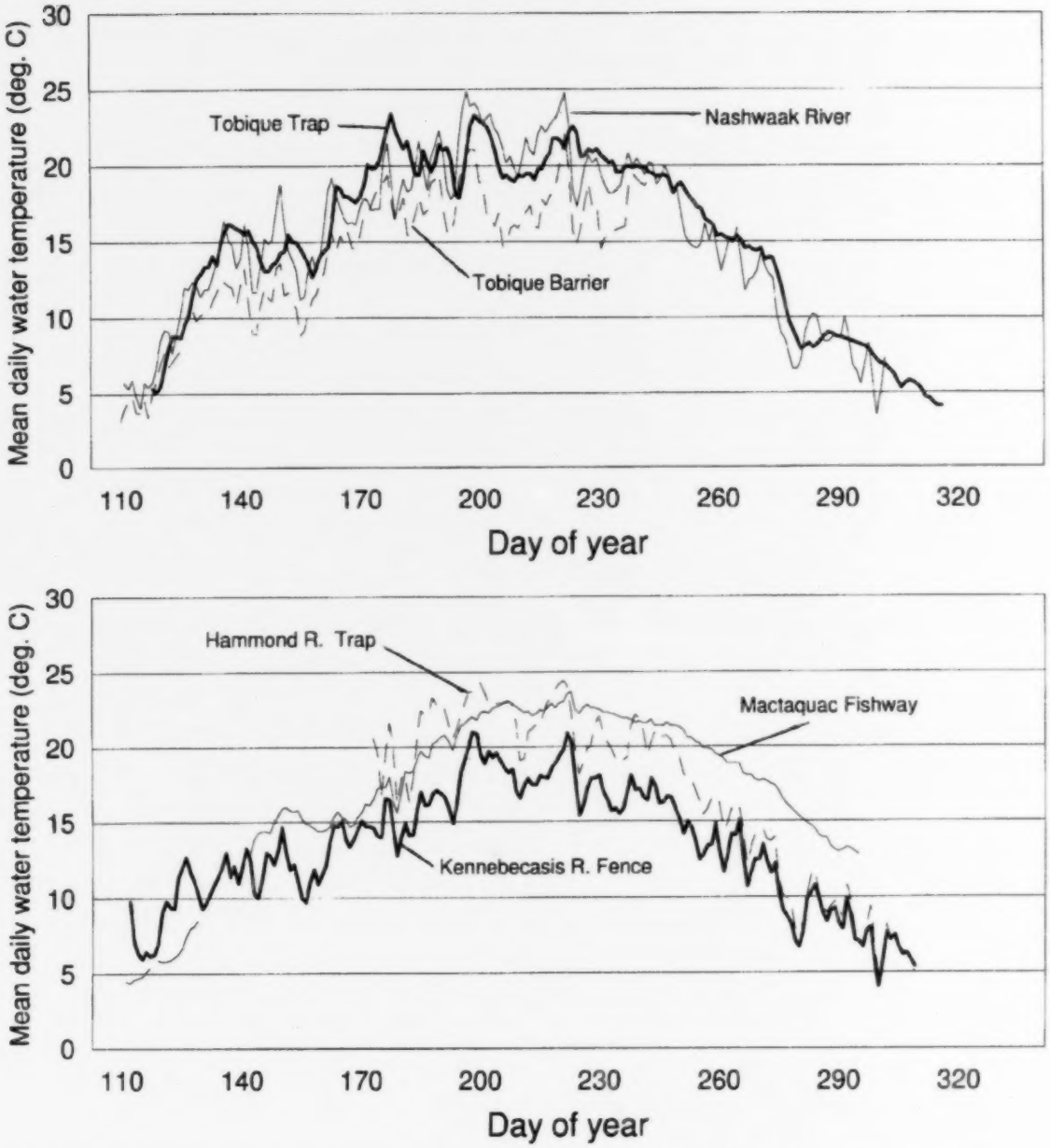

Figure 6. River water temperatures for different locations in NB in 1998. (day 110 =April 20).

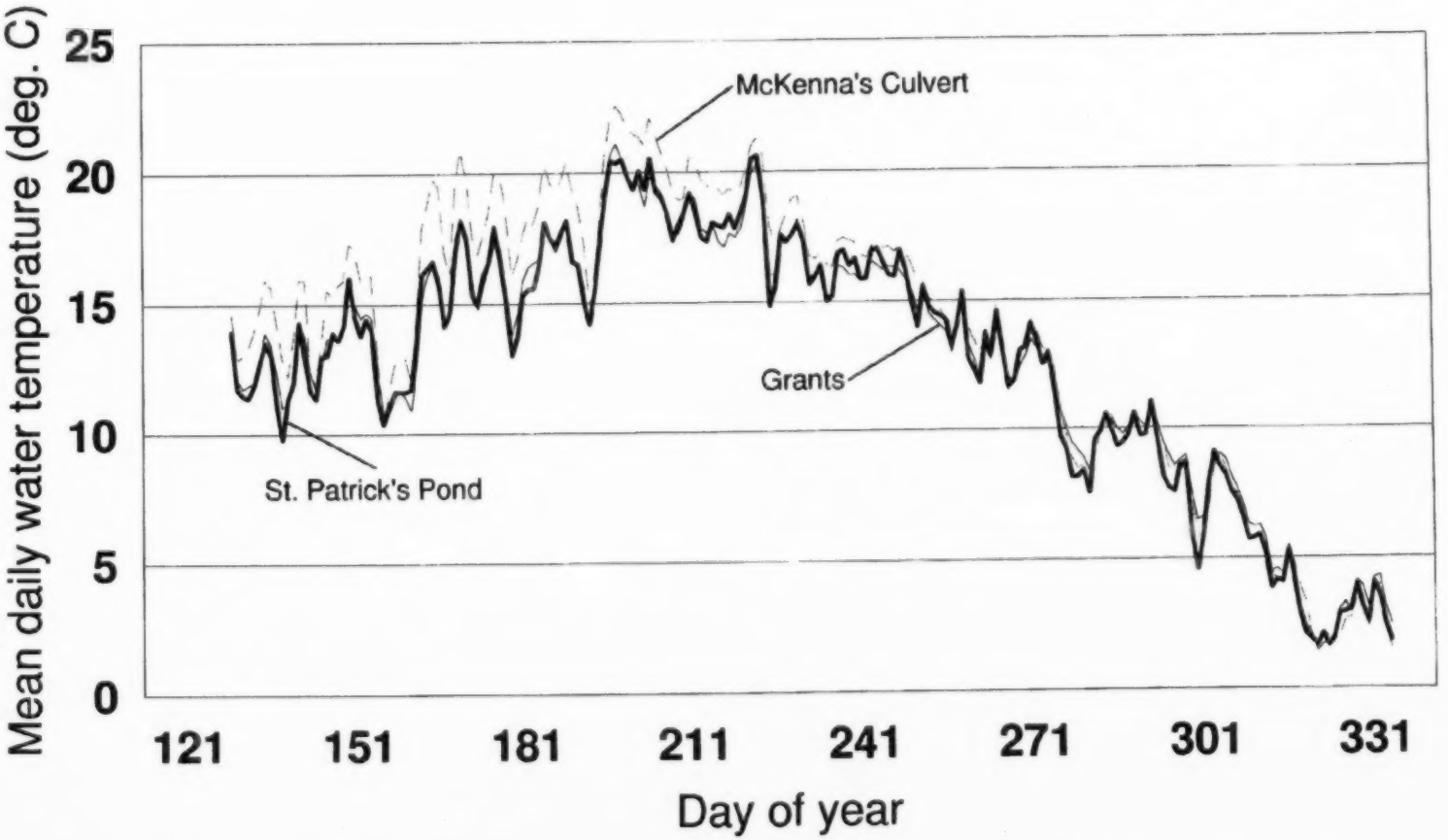

Figure 7. River water temperatures in the Morell River (PEI) in 1998 (Day 121 = May 1).

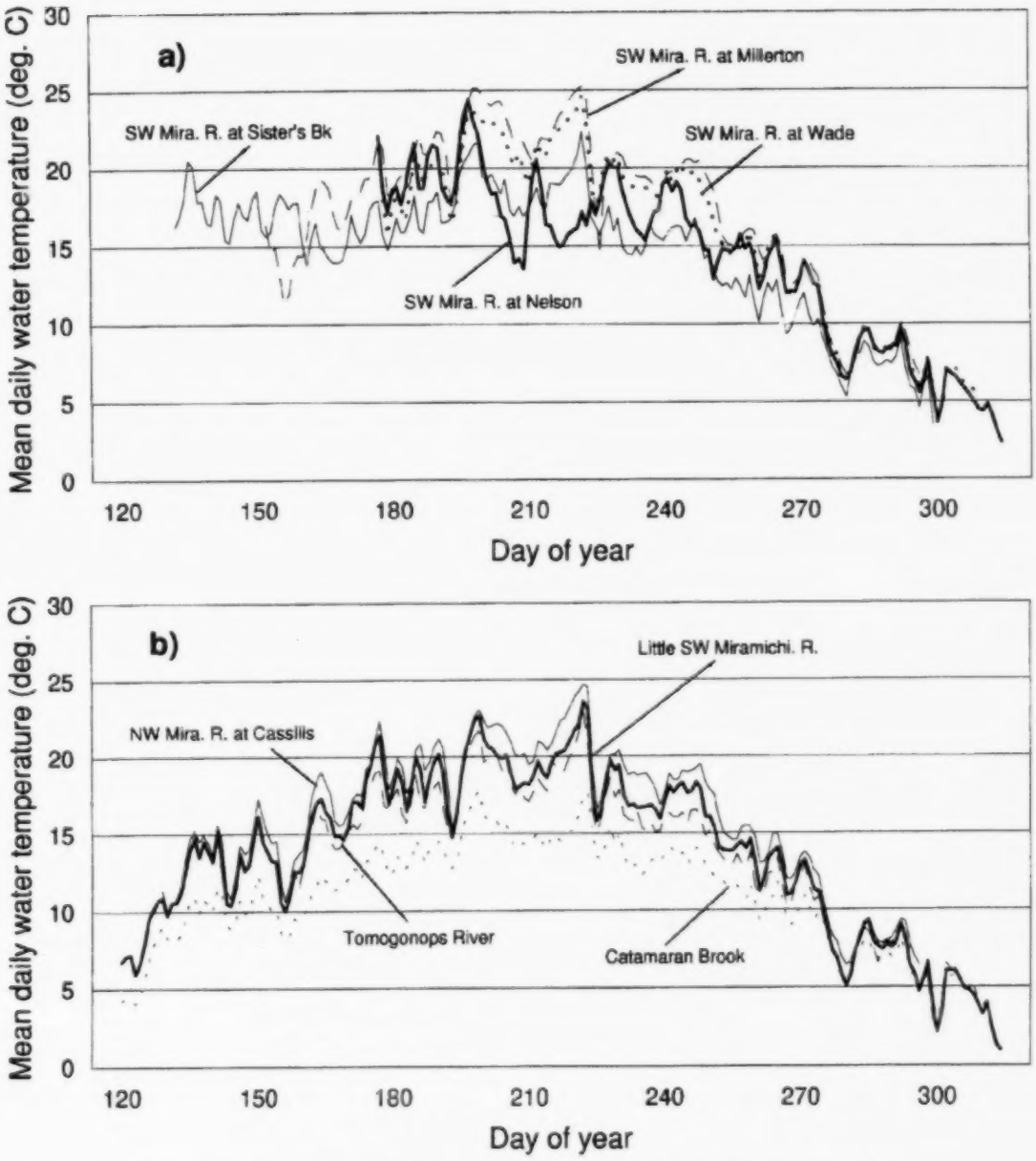

Figure 8. River water temperature in the Miramichi River, 1998. (day 120 = Apr. 29).